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Cross-Cultural Teaching of Science

Study of the intellectual environment in which children live may lead to better science teaching.

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A major theme of our age is the development of science and technology in societies around the world. Leaders in most of the developing countries of Asia, Africa, and South America, where knowledge and utilization of natural resources have remained nearly static over the past several centuries, now recognize that they must move into the era of applied science and technology if provision is to be made for the needs of increasing populations and for improved standards of living (*1*). Thus, technology and science are emphasized in their development plans and in the assistance they seek and receive from nations such as the United States (*2*). It is generally assumed that this process of scientific and technological development will require very much less time in Asia, Africa, and South America than it did in Europe and North America, and in fact many countries hope to achieve in one or two generations changes comparable to those that occurred in the West over 2 or 3 centuries. Their hope is based partly upon the availability of capital assistance from the industrial nations and partly upon the ease and rapidity with which knowledge now at hand can be communicated—knowledge which was originally obtained over a long period in a process involving many errors and confusions that will not have to be repeated. In their optimism they largely ignore the profound social and cultural changes that accompanied the Western development and the social and cultural changes that must accompany this new scientific revolution. Frequently it is found that a country whose leaders are determined to introduce rapid change is not ready to adopt modes of thought and organization that are fundamental to an advancing science and technology, and hoped-for results have been slow to materialize. It should be added that unnecessary ambiguity has sometimes resulted from a failure, in discussions such as this one, to distinguish between technology and science (*3*). In what follows we are concerned specifically with science and with problems associated with its introduction.

The difficulties encountered frequently relate to the very nature of the interaction between Western science and non-Western cultures, an interaction that has received little study in spite of the fact that it lies at the very heart of the development process. Western technology developed out of the Western scientific revolution, which, over the last 3 centuries, has profoundly altered Western man's understanding of, and relation to, nature. The resulting "scientific viewpoint" has become our way of considering reality, and it is so much a part of us that it is taken for granted. The traditional cultures of Asia or Africa, however, are frequently nonscientific—nonrational in their approach to nature—and they do not always provide a ready foundation upon which to build a more scientific view. Of course people of all cultures experience many of the same familiar phenomena of nature and feel that they understand what is real and how knowledge about the real world is to be organized. Interpretations of what is meant by the "real" world, however, vary widely. Major tasks, then, are to determine what constitutes reality for persons of different cultures and to learn how the most meaningful communication about nature can be established among people holding different views of reality. The first of these tasks has been undertaken, with particular attention to science, by Malinowski (*4*), Hsu (*5*), and others (*6*), but our knowledge is far from complete; the second has hardly been touched on, except as it relates to science education within the Western countries.

Science education, in any country, is certainly a systematic and sustained attempt at communication about nature between a scientific and a nonscientific, or a partially scientific, community, and as such it should be particularly sensitive to the attitudes and presuppositions of both the scientist and the student. In fact, however, the teaching of science is often singularly insensitive to the intellectual environment of the students, particularly so in the developing countries, where the science courses usually offered were developed in a foreign country and have undergone little if any modification in the process of export. Why should we suppose that a program of instruction in botany, say, which is well designed for British children, familiar with an English countryside and English ways of thinking and writing, will prove equally effective for boys and girls in a Malayan village? It is not merely that the plants and their ecology are different in Malaya; more important is the fact that the *children* and *their* ecology are also different.

We are convinced that a study of the intellectual environment in which children live can lead to significant improvements in science teaching and science learning. This is of particular importance, moreover, to the developing countries whose environments are very different from those of the West

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and whose educational resources are so limited as to make any increase in efficiency very desirable. We discuss in this article an initial effort in that direction, some pilot experiments conducted in Nepal during October and November of 1965.

Experimental Setting and Procedure

Nepal and its people remained effectively isolated from Western intervention or education throughout the entire colonial period of European influence in Asia, the only important exception being the Gurkha mercenary soldiers who returned to their villages after a period of service in the British army, bringing with them the accumulated experiences of several years of travel and contact with foreign places and ideas. Only within the last dozen years has there been any opportunity for Western education or science to reach appreciable numbers of Nepalese communities, and there is now a considerable range in the degree to which they have penetrated into village life and thought. The government is actively supporting the development of education, as to both quantity and quality, through increase in the number of schools, establishment of a modern teachers college, development of a national university, and other measures. These circumstances, together with the practical consideration that one of us (P.L.P.) is a native of the country, with knowledge of the language and customs, dictated our choice of Nepal for our investigations. (It should be added that each of us has spent several years living and working in the other's native country.)

We decided to investigate three widely separated ethnic communities having quite different histories of outside contact: the Newars of the Kathmandu Valley, the Limbus of eastern Nepal, and the Gurungs and Chhetris in the west of Nepal. The sacrifice in depth which this decision entails is justified by a need, at least at this early stage, to determine how widely applicable our conclusions might be. The Newars have, for many centuries, been the principal inhabitants of the Kathmandu Valley, where they have developed a rich artistic and literary heritage. They include many skillful artisans and enterprising merchants within a predominantly agricultural economy. They are conservative, adhering rigidly to an inclusive, self-consistent social and philosophical orthodoxy. The Newar town of Panga, where we worked, is a closely packed unit of narrow paved streets and three-story brick houses surrounded by fertile rice fields. Many of its citizens make frequent trips to Kathmandu, the cosmopolitan capital no more than 8 kilometers away, and some of them work there regularly, yet Panga is in most respects an island which might just as well be 500 kilometers or 5 centuries away. Its people are shy, friendly, and hospitable to strangers, but they express little curiosity about a visitor's thoughts. The town has both primary and secondary schools with trained teachers, but fewer than one-fourth of its school-age children attend school.

In contrast, the Limbu village of Tokma is several days' walk from any motor road, airfield, or city. Its dwellings are scattered widely over a large and fertile hillside, which provides ample income to the inhabitants, all of whom live by farming. There is no school or store or other business establishment in the village itself. The villagers have the reputation, shared by all Limbus, of being proud, quick to anger, and fiercely independent. They have resisted political domination, and they take pride in an independence of mind which resists the importation of orthodoxies from outside. Their religious life combines Hinduism with shamanism and witchcraft, and they maintain unique customs not shared by other Hindus (*7*). They are reserved and suspicious of visitors but not hostile, adhering carefully to established rules of courtesy.

Finally the Chhetri and Gurung people of Armala Dihi are open, friendly, and relatively poor farmers who will sit for hours asking questions about a stranger's experiences and opinions and about the world he comes from. Many Chhetri men serve as Gurkha soldiers, and nearly every village has one or more members who have returned from such service to live in retirement as respected and influential citizens whose pension payments add significantly to the economic well-being of the village. In Armala Dihi there is a small primary school but no store. There is a good middle school about an hour's walk away. Whereas in Tokma we were the guests of a wealthy Limbu landowner for several days without once being invited to enter his house, our host in Armala Dihi insisted that we move into his own room, sleep in his own bed, share his meals, and use the best of everything he could provide.

We sought information about attitudes toward familiar phenomena of nature, and about the sources of knowledge about nature, through interviews with school-age children, typically 9 to 14 years old, and with adults of an age to be these children's parents. The interviewing was kept informal and usually involved small groups of three or four individuals at a time. The main content and order of the interviews was held constant for all groups.

The questions were of three types, designed to reveal (i) how the respondents accounted for various commonly experienced phenomena, such as rain, lightning, thunder, fire, and earthquake; (ii) what attitudes the respondents held about the control or manipulation of such phenomena; (iii) what were considered to be the origins of knowledge about nature, and what the accepted criteria of validity of such knowledge were. Typical questions are as follows.

Category i. How do you account for rain? Where does the rainwater originate? What do most people in the village think about rain? What makes an earthquake?

Category ii. How can rainfall be brought about or prevented? Is it appropriate for men to influence the rain? Is there any protection against lightning or thunder?

Category iii. How were these things (about rain, and so on) learned? How does one know if they are true? How might new knowledge about such things be obtained?

In addition, observations were made of the kinds of opportunities available to children for learning and practicing skills of abstraction and manipulation that could later be a help in learning and using science. As a test of ability to represent real situations by means of an abstract model, each respondent was asked to sketch a rough map showing how to get from his house to the school.

For comparison, similar groups of American primary school children, aged 9 to 12, attending the University of Hawaii Elementary School in Honolulu, were interviewed and asked to sketch maps. About half of these children were Caucasian, the others being of Asian and Polynesian origin. All had been brought up in Hawaii among typically Western surroundings of American games and toys, American magazines and television programs, and all the great diversity of intellectual and physical stimuli to be found in a city such as Honolulu.

The Nature of Phenomena

Throughout the interviews, in both Nepal and Hawaii, our interest was directed not toward the "correctness" of a response, as judged by accepted scientific or other standards, but rather toward the type of the response itself and the relation to nature that it suggests—whether, that is, it suggests an explanation of phenomena that is mechanistic, supernatural, teleological, and so on. If a given statement can be recognized as referring to a certain religious belief, for example, that recognition serves our purpose, and we are not concerned with whether or not the pertinent religious scripture is accurately quoted or even explicitly referred to.

With very few exceptions we were given both a "folk-oriented" or "myth-oriented" and a "school-oriented" explanation of a given phenomenon within a single interview, sometimes by a single individual. Thus, to account for earthquakes, one of a group of four Chhetri boys said, "The earth is supported on the back of a fish. When the fish grows tired it shifts the weight, and this shakes the earth."

All agreed, but another added, "There is fire at the center of the earth. It seeks to escape and sometimes cracks the earth, causing an earthquake." All agreed to this as well.

In a group of Newar school children (four boys and a girl) these statements were given in answer to the same question:

"The earth is supported by four elephants. When one of them shifts the weight to another shoulder an earthquake results."

"There are fire and molten metal inside the earth which try to escape. They may crack or move the rock of the earth, causing an earthquake."

Again all agreed to both statements.

This pattern is repeated again and again:

"The deities break vessels of water in the sky, causing rain."

"The sun evaporates water from the sea, producing vapor which is cooled by the mountains to make clouds and rain."

* * *

"Lightning comes from the bangles of Indra's dancers."

"Lightning comes from the collision of clouds."

* * *

"It rains only in the summer (monsoon) season because we need the rain then. In winter we do not need rain."

"It rains in the summer because the sun is hotter then and causes more evaporation."

* * *

The replies given by Newars, Limbus, and Chhetris are very similar in content, evidently reflecting a common background of mythology and of school curricula, a similarity which is not very surprising, for the three groups, with all their differences, do in fact have a common school system and, in the main, a common religion. More surprising is the fact that each group nearly always gave answers of both the types illustrated above, and that all the members generally accepted both. Of course there is nothing unusual in the thought that a given phenomenon may result from either of two different causes and hence that, in general, each of these causes may be accepted as potentially valid. However, here the two types of "causes" offered appear to be qualitatively so different as to be mutually incompatible, for they suggest conceptually very different ideas of nature. Examination of the replies quoted shows that they do not admit of the type of synthesis which states, "God is the source of rain. He produces rain by causing the heat of the sun to evaporate water from the sea. . . ." It is as difficult for us to accept both as real alternatives as it is to accept them as simultaneously true.

The contradiction is far more apparent to us, however, than to our respondents, who showed no discomfort over it, a fact which should serve to warn the science educator that all is not as it appears on the surface. The philosophies and literature of Asia make great use of paradox, and, to Asians, contradiction may be more intriguing than disturbing. We should not, therefore, discount the possible existence of very deep-rooted patterns of thought not consonant with the "either-or" logic underlying Western science, the logic which makes it so difficult, for instance, for American students to accept the concept of complementarity in modern physics. However, a simpler explanation should also be considered. Much of the teaching and learning in Nepalese schools involves rote memory only and demands very little understanding or conceptualization. Furthermore, many of the teachers and textbook writers belong to the Brahman caste, the priestly class traditionally responsible for the teaching and preservation of orthodox religious beliefs and practices. It is quite possible that, even without any conscious intent on their part, these teachers and textbook writers have taught early "scientific" concepts in such a way as to produce, in combination with a tradition-oriented home environment, a dual view, according to which distinction between myth and science is unnecessary. Even in science teaching in an American elementary school the amount of teleology used is not inconsiderable. In any case, this dual view of nature is a matter that needs to be considered in the planning of revised science teaching methods.

No such duality was evident concerning the control or manipulation of nature (which was always considered appropriate although not always possible). To questions such as, How can rainfall be brought about or prevented? or, Is there any protection against thunder (lightning)?, a single type of reply was always given. Usually control of such natural phenomena is expected to follow from a religious ritual in which it is made explicit that actual control is at the will of a deity who may not always respond. Thus control is uncertain. In some instances, as when the farmers want hail deflected away from crops, the resort is to magic or charms performed by special persons and not associated with a religious ceremony. Charms too may fail, and all such procedures remain ambiguous enough in principle to make convincing empirical tests of their validity hard to manage. Of course there are many common and well-understood technological manipulations of nature which are taken for granted and explained in operational terms. Such is the case, for example, with irrigation, the cooking of food, or the firing of clay vessels.

In no single instance did a member of any one of the groups of Honolulu school children manifest a comparable duality of viewpoint. The explanations offered in answer to the same questions about rain, lightning, and so on were not always factually correct, but they were always "scientific" in concept and usually mechanical. Lightning is produced "when two clouds collide"; the heat of the sun evaporates and "lifts" water up to make rain; parts of the earth "shift," causing earthquakes, and so on. On two occasions the Biblical story of God erecting the rainbow as a promise to the children of Israel was mentioned, and each time the respondent spontaneously pointed out that this is a different kind of statement and not an explanation of rainbows.

None of the members of the comparison groups in Honolulu believed that control or manipulation of natural phenomena of the kinds under consideration was achievable through magical or religious practices; they considered such control either achievable through technological procedures or impossible. Many, but not all, of the individuals who said control was impossible suggested that it might in time become possible. Sometimes procedures were described which are not used and would not work, such as the use of lightning rods to convert lightning into ordinary house current, but even these procedures were always presented as scientific, technological processes without any occult or supernatural element.

The Nature of Knowledge

When our Nepalese respondents were asked to give the source of their knowledge about nature they invariably said that it came "from books" and "from old people." When we asked how the old people found out or how knowledge got into the books they told us it came from earlier generations of "old people" or from other books. When we pressed for some ultimate source, most of our respondents said that these things had always been known, although a few of them referred to legends telling how some particular skill, such as fire building, was given to men by the deities. One Chhetri student suggested that some knowledge might have been obtained by "accidental observations."

We went on to inquire how knowledge hitherto unknown to anyone might be acquired or how it might be sought. We were always told that such new knowledge is not to be expected. Even when we pushed this question so far as to call attention to such "new" discoveries as space travel or transistor radios, which all Nepalese know about, it was held that such things were always known by someone, or else that these are merely new applications of old knowledge. One very tentative exception was offered by a Limbu boy, who suggested that really new knowledge might sometimes come through dreams. We find it hard to believe that more probing would not reveal other exceptions, yet the predominant view is one that pictures human knowledge about nature as a closed body, rarely if ever capable of extension, which is passed down from teacher to student and from generation to generation. Its source is authority, not observation. In fact, experiment or observation was never directly suggested to us as an appropriate or trustworthy criterion of the validity of a statement, or as its source. When one of us stated that a book, after all, is only a more permanent record of someone's observations, the idea was treated as novel and faintly suspect. Given this concept of knowledge, it is no surprise that the schools rely heavily upon rote memory. Memorizing would seem to be the easiest and most efficient way to deal with a closed and limited body of unvarying facts. There are also other well-known and frequently criticized forces embedded within the formal educational system which strongly reinforce this natural tendency.

It should not be thought, of course, that it is only in Nepal or Asia that students try to learn science by memorizing. Our comparison group in Honolulu showed evidence of considerable, though more limited, reliance on the memorizing of facts given in a book or stated by a teacher. However, members of the Honolulu group all stated that the knowledge originated in observation and experiment, and they believed that new knowledge not only can be obtained but continuously is being obtained.

Use of Abstractions

Science as the scientist thinks of it and would like to see it taught consists, not of a body of more or less isolated facts to be memorized, but of a system of empirically verifiable relationships between more or less abstract concepts. While the concepts are derived from real phenomena, the relationships of science relate concepts, not real objects, and the theories of science are built around "models" which portray in abstract, often mathematical, terms a selectively idealized representation of real phenomena. It is essential for the science student to learn to be at home, at some level of sophistication, with this process, which must surely appear even to the Western layman to be extraordinarily indirect. Much attention is given to this in the recently developed or improved science courses in the United States, which go to great lengths to give students systematic training and practice in skills of abstraction and inference while striving to maintain contact with the real world by subjecting conclusions to observational verification. Of course, informal learning plays a part in this process. The toys children manipulate, the games they play, the activities of the adults they watch and imitate, the conversations they listen to all contribute to the attitudes and skills they develop (*8*). In everything the child does in school there is an echo of his environment at home.

How much more difficult science must be, then, for a child who lives in a Nepalese village or small town, immersed in a very different environment with its own pervasive non-Western influences. Here he lives close to nature in a direct, particularistic relation of planting and harvesting, with little or no abstraction and little need to generalize. He does not play with mechanical toys or build mechanical models; he plays or watches games of skill or chance but knows little about games of strategy; he rarely sees a book in his home; he rarely has occasion or opportunity to deal with derived or inferred properties or concepts. Certainly his society, or any society, contains a great many abstractions, ranging from spoken or written language all the way to a very complex religious cosmology, but these are not all particularly useful in preparing the way for science, which wants to hold to a rather special and verifiable relation to nature. Thus, for example, every Nepalese child will be familiar with abstract representations of certain Hindu or Buddhist deities and heroes of religious myths and legends, yet these are not subject to direct or even indirect observational verification, after the manner of science, and they may not be conducive to a scientific approach.

A thorough analysis of the informal intellectual environment, even in one of the groups we visited, would be a major undertaking which we did not have the resources to undertake. Yet we did want to include some tentative assessment of the effects of informal learning as it might bear upon science learning. For this purpose we asked our subjects to sketch rough free-hand maps showing how to get "from your house to the school" (or to some other well-known local landmark). A map is a fairly simple, yet typical, example of a scientific model. It preserves a verifiable 1-to-1 relation to reality and yet it is an abstraction, useful for what is omitted no less than for what is included. Mapping allows for great variety in the way a given reality is represented, and the relationships and inferences derived from a map, while not totally unrelated to reality, nevertheless actually refer to the model and not to the real world. We believe that the maps which children (*9*) or adults draw to represent a well-known route or neighborhood will reveal with some accuracy their readiness to understand and use other scientific abstractions.

The "maps" we obtained from the Nepalese respondents are all very similar to each other and to the example shown in Fig. 1. Always they include a recognizable *picture* of "my house" and of "the school," the two being connected by a line which seems to denote *the process of going* from one to the other, not the spatial relationship of one to the other. Thus, the two buildings represented in Fig. 1 are not in fact on the same street or path, being separated by several street intersections and other landmarks, none of which appear on the map. In contrast we show (Fig. 2) a map typical of those drawn by American children in response to the same instructions. Here both house and school are represented by abstract symbols, not pictures, and there is a clear effort to show spatial relationships and to provide needed spatial clues. The propensity of the Nepalese for making maps (whether verbal or graphic) which are *sequential* rather than spatial constructs is not limited to school children. In a land of foot trails, where literacy is too low to justify the use of signs, this propensity has been a source of consternation to more than a few travelers of Western upbringing! We, too, in reply to our inquiries as we traveled, were given instructions or "maps" which, like a string of beads, list in correct sequence the places we should pass through without giving any clue as to distances, trail intersections, changes of directions, and so on. Our interest is not in the accuracy or potential usefulness of this different kind of model but in the light it may shed on a way of thinking which may extend far beyond mere map making. The villagers use no other kind of map; they do not use drawings in constructing a building or a piece of furniture—in fact they hardly use drawings or spatial representation at all (except for records of land ownership, which does not change very frequently), and the lack of spatial models may be very natural. One wonders, however, whether the science teacher will have this in mind when he presents a model of a molecule or the solar system.

Variations between Groups

Our observations were the same for all three of the Nepalese groups we visited. No doubt this is partly due to the rather gross nature of the study, which may bring out only the most obvious and general conclusions where a finer-grained, more extensive study could be expected also to reveal characteristics that pertain to one group only. From the standpoint of science education, however, it is useful to start with observations that lead to widely applicable recommendations, and this has been a factor in the design of our study. Certain differences between groups are suggested by the results of our interviews, however, and we mention below two that might well be of further interest.

Although observation was practically never suggested explicitly by any group as a reliable source of knowledge, we did find many indications among Limbu respondents that observation of nature plays an important role in shaping their attitudes, and also that they feel a need for observational support of theories to an extent not found in either of the other groups. Thus, whereas our Newar respondents always had a firm answer to every question, it was not uncommon for a Limbu to give a reply and then add, "it seems so, but we are not sure," or even to admit that he had no explanation of a given phenomenon. All groups described the rainbow as a manifestation which draws water up from lakes or rivers into the sky. However, more than one of the Limbu respondents pointed out to us that a rainbow

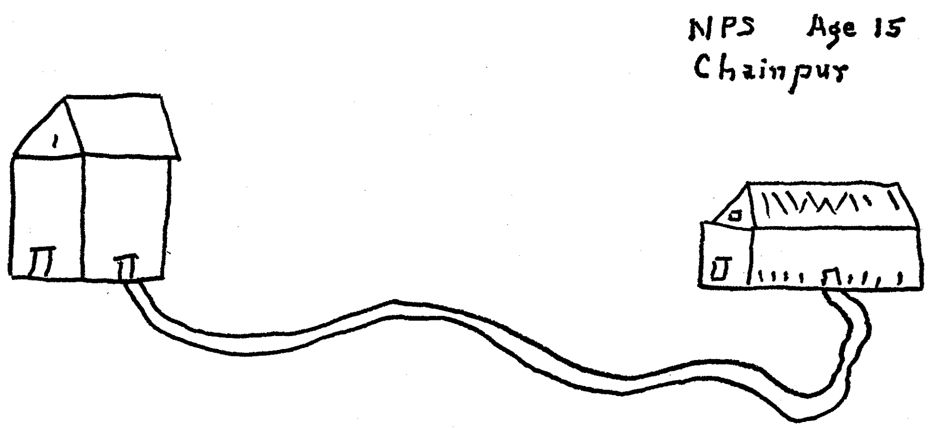

Fig. 1. Map drawn by a 15-year-old Limbu boy to show the way from his house to the school. In fact, the house and school are not on the same street or path.

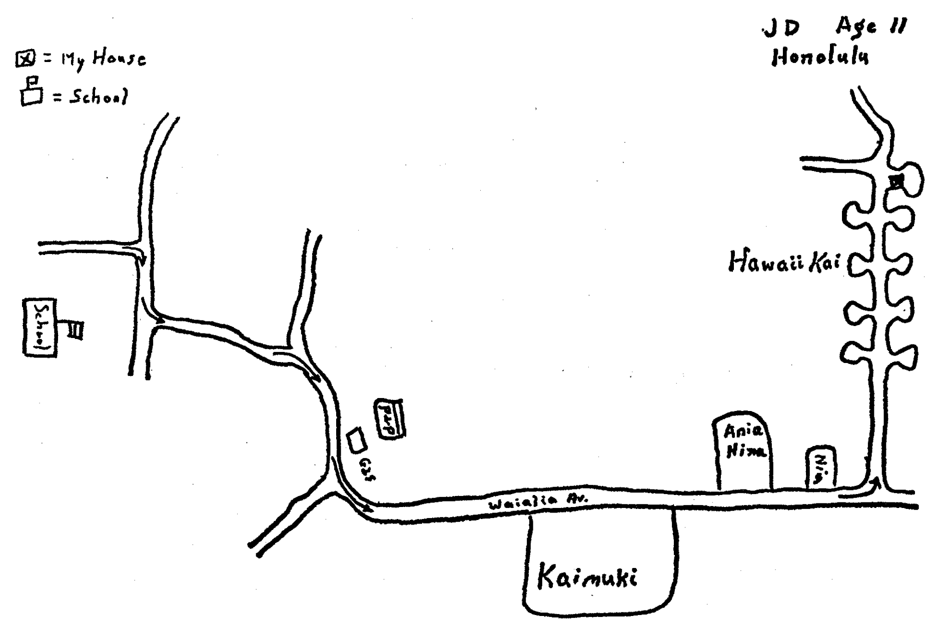

Fig. 2. Map drawn by an 11-year-old American boy to show the way from his house to the school. Note the wealth of spatial and directional clues.

may be seen in waterfalls when the sun shines on them, "and so it must have something to do with light and water spray or vapor."

Newar respondents always attributed lightning damage to a particular variety of thunder (*10*), literally "ax-thunder" (we refer to it here as a "thunderbolt"). They describe it as a material object, shaped like an ax, which falls from the sky during a thunderstorm and returns to the sky again, splitting or smashing things on its way. They offer no evidence to support this description, except to refer to the knowledge of old people, if evidence is demanded. When we asked Limbus about thunder and thunderbolts we were told essentially the same thing, with the added information that "thunderbolts" are black in color. We did not question this explanation nor ask for any evidence, yet in a few minutes one of the informants produced a small, black stone artifact shaped like an ax-head. He explained that it was a "spent thunderbolt" which had been damaged when it struck the earth and, being imperfect, could not return to the sky. Further inquiry indicates that such artifacts are occasionally found on the ground or in rice paddies. They are not made from locally available stone and are not believed to be of human origin but are always taken to be "thunderbolts." They fit the mythological concept of "ax-thunder" closely enough to make identification of them in this way very natural, provided a need for observational support of the theoretical concept is felt. Obviously our informant felt that, in our minds too, this evidence would support his explanation.

This experience was duplicated in every essential detail in the community of Armala Dihi 300 kilometers to the west, where we were again presented with a stone-age "thunderbolt"! Other evidence of a need for empirical observation was less strong, however, in Armala Dihi than in Tokma.

Finally, there are differences among these three groups in the degree of stress produced as a result of new ideas from the West. All groups and all individual respondents know that change is coming rapidly to Nepal and that many new ideas are reaching the young people through the rapidly expanding school system. Among the Chhetris of Armala Dihi this is evidently a source of much personal and intergroup tension. The adults welcome schools and urge or require their children to attend them, yet they are engaged with the children in a continuing and sometimes strenuous dialogue in defense of the old ideas and cosmology—a dialogue in which both adults and youths did their best to enlist our participation. Although the adults clearly identify themselves with the old order, they are intensely curious about the new. They seem not to tire of asking questions that range widely over a world of ideas just visible over a still-distant horizon. None of our respondents had served as Gurkha soldiers, but, as we have pointed out, the region includes many individuals who have. In contrast, the Newars of Panga, certainly the most conservative of the three communities, show very little curiosity about the world outside Panga and evidence very little concern about what their children may be learning. The Limbus, too, showed little concern about foreign ideas, which they know about but do not perceive as threatening. They seemed to show a similar lack of concern about a number of introduced Hindu rituals which are practiced and yet disclaimed as foreign and of no value. Such patterns of receptivity or rejection of change and the stresses they lead to in individuals or families are, of course, too complicated to be treated here. Yet they are important to the processes of development and education, and they deserve careful study in considerable depth.

Implications for Science Education

The foregoing observations suggest changes in method or content which might lead to easier and more economical, as well as more effective, teaching of science in Nepal. We believe that some of these changes will be found to apply more or less well in many other developing countries, and we hope that similar, or more refined, studies will be undertaken which will extend and, hopefully, corroborate our conclusions. For the present we shall limit ourselves to a few relatively clearly indicated changes that could be introduced on a pilot scale.

It is clear that the school-age boys and girls among our subjects do not have the attitudes about nature and learning that are most conducive to an understanding of science. Clearly, too, they have not developed much skill in abstract representation, measurement, and so on—skills which contribute not only to scientific experimentation but to conceptualization as well. It is now well accepted that such attitudes and skills can best be developed relatively early in a child's school experience, well before the introduction of formal subject-matter courses like chemistry or physics. We believe that a program of pre-science instruction in the elementary grades, similar to programs now under development in the United States (*11*), will be both possible and very desirable in Nepal and probably in other developing countries. This instruction may well follow the general guidelines that have been laid down for the American efforts, but it will have to be adapted to conform closely to the particular environment, needs, and available resources of the country and community where it is used, and it should start with the questions children ask there. The project will involve program design and teacher training but no difficult economic problems pertaining to equipment or supplies, for local "phenomena" for observation are best and are abundant; "laboratory material" will consist of leaves and pebbles, sunshine and seeds; and equipment will consist of pieces of bamboo, locally available utensils, and so on. Such a program can certainly present real phenomena and teach real facts, but its fundamental intent is to provide a basis of skills and attitudes and a relation to nature, rather than facts as such. In a school system that relies heavily on memorized factual content this will be a delicate undertaking.

We have noted the prevalence of a dual view of nature or reality which was especially striking because the two views expressed seem to us contradictory, although accepted simultaneously by our subjects. If this paradox is new in Nepal, it is certainly not new to the West. The same ambivalence has run through Western thought at least since the early scientific revolution, and it is still with us. What scientist in the West has not heard the question, But how can you be a scientist and still accept that view? or has not at one time or another agreed to speak on "Science and Religion"?

Yet for the most part we in the West have been able to make our peace with the complementary worlds of matter and spirit, of objects and values. Through careful delineation of boundaries, conscious and unconscious compartmentalization, or reinterpretation, and a variety of intellectual nonaggression pacts, a reasonably secure and peaceful coexistence has been achieved, so that this particular dualism no longer poses serious problems for the Western scientist or student. Can others be helped to achieve or preserve a coexistence that does not violate their cultural values as they try to assimilate our Western science and scientific viewpoint?

We propose, as one step, that science be presented as a "second culture," complementing that already present rather than replacing it, and taught in the spirit in which a second language is taught—to be learned and used, certainly, but not to the exclusion of the student's native tongue. This will require a very different orientation from that commonly found in most Asian schools, or indeed from that characteristic of most Asian-American relationships, even if it does not mean great changes in school curriculum. Beginning with the earliest missionary schools and continuing through the period of colonial schools, the attitude, and often the intent, of Western education has been that a "primitive" or "decadent" civilization is to be replaced with a more modern and "better" one (*12*). This attitude tends to continue even though colonialism is no longer a force behind it, and it tends to be particularly strong in science teaching, for science is taken to be the one really unique and powerful offering of the Western world. In fact, however, the purpose of education, whether in Nepal or elsewhere in Asia, is no longer to destroy one civilization, or even one set of ideas, in order to replace it totally with something that is conceived to be better; to proceed in that direction, or with that implicit attitude, is to create unnecessary difficulties along the way. An implacable either-or approach, leading to a direct confrontation between traditional attitudes and a modern and very foreign approach to knowledge, invites conflict both within the student's own mind and between him and his elders in the community.

As has been seen too often, such a conflict results at best in a draw, which alienates from one world without really admitting into the other. We propose to avoid or postpone this confrontation by starting early science instruction with simple observations of ordinary things and events—observations which stimulate and use the child's latent curiosity, which anyone can make, and which demand no special or formal interpretation in cosmological or philosophical terms. Instead, this approach will provide a foundation of skills, of attitudes toward observation, and of specific observations upon which a more formal knowledge of science may later be built. In making this proposal we accept a complementarity of views as natural and perhaps as inevitable.

We are mindful of certain arguments that favor, in principle, the opposite alternative of immersing the student in the Western scientific culture, through study in the West, and demanding that he learn it and conform to it totally. Of course, this "total immersion" would not be possible for most Nepalese children or adults, the vast majority of whom do not in any case expect or wish to become scientists. Beyond this lies the fact that any who were to succeed in such a "total immersion" and then return to work and live in Nepal would be sure to find themselves seriously alienated. To a considerable degree this does happen to Asian graduate students who leave home to study in the United States and then, partly because of the consequent alienation, find themselves unenthusiastic about returning home. Once immersed, one is more comfortable to remain so.

We are mindful, also, of a seeming contradiction in our proposal. If extensive social and cultural changes are bound to accompany the introduction of science, is it wise to ignore this in preparing the child for learning science? We believe that it is. Of course, some kind of accommodation between the scientific revolution and Nepalese culture must and will eventually be reached if science is introduced at all. This is a complex matter which must evolve slowly within the Eastern cultures as it did in the West. Experience suggests that this accommodation will not be most easily achieved simply by substituting the one for the other, and particularly not during the school years when the children are immersed in the intellectual and physical environment of the village. It is important to them and to the village that they remain at peace there. Moreover, an eventual accommodation should be based upon real science well learned rather than on a set of memorized facts and formulas learned under stress.

To refer again to the analogy of language teaching, recent experience seems to show that the attitudes and techniques used in teaching English to, say, Urdu-speaking children, where no question of substitution or conflict arises, are the most effective in teaching a standard English to children, in Hawaii or Georgia, for example, who speak a "substandard" dialect of English. It is easier for these children to learn standard English when it is presented as a second language, not as a substitute for their own "incorrect" dialect, which of course they continue to need in their own community.

Elementary Science Instruction

A detailed program of instruction in science (many might prefer to call it pre-science) is under development in Nepal, partly as a result of the observations reported above. It would be premature at this time to anticipate its final dimensions or content, but we may say a few things about its methods and goals. Emphasis will be on an observational approach to phenomena which are familiar to anyone, or which can readily be produced by anyone, and a progression of skills and experiences will be built up, encompassing classification, measurement, generalization, inference, and quantification, and leading ultimately to the design and execution of elementary but conceptually more or less sophisticated experiments by the students. The material presented will contain some specific information intended for later use, but this will not receive major emphasis and need not be memorized. In addition to the observational material, some history of science will be introduced, in essentially anecdotal form, to show that knowledge of "books and old people" is really a record of observations and interpretations made by real people.

The educational system of Nepal, like that of many other countries, is fairly rigid and is not amenable to rapid change or experimentation. Nevertheless, we see it as necessary that improvements, to be lasting, be developed within the existing system, however time-consuming that may prove to be; hence, such efforts must have the understanding and active support of those persons who are in positions of leadership and authority within the system. The program we are proposing will be developed within the Education Ministry and tried out in the laboratory schools of the College of Education of Tribhuwan University. Further trial and development with the help of Peace Corps teachers, now working in many schools throughout the country, is anticipated. These Peace Corps volunteers are enthusiastic, well accepted, and devoted to the improvement of education. If the program has the endorsement of the government, they will be ready to try it out with very little feeling of hesitancy because the teaching methods are new and different. Moreover, there is reason to hope that the interest in better science teaching which has resulted from the American experimental curricula in secondary school science will result in changes and improvements in Asia, and perhaps in Nepal, affecting the teaching of science at the secondary level. These American courses, as well as other studies (*13*), emphasize observation and experiment. We hope that a program such as the one we propose for Nepal at the elementary levels will provide a useful preparation for more formal course changes patterned on the American model. In fact, we believe that some such preparation will be found necessary if science courses based on the American experimental courses are to maintain their spirit and emphasis as they are adapted for use in Asia.

In concluding, we must emphasize that much of what has been said is tentative, based as it is on a limited pilot study. Yet the study does indicate that research of this nature can provide needed perspective for the improvement of science teaching in non-Western countries. We hope it will lead to more study and discussion, with regard both to Nepal and to other developing countries.

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Human Echo Perception

Behavioral measurements are being made of human ability to detect objects by use of echoes.

Charles E. Rice

Some bats and porpoises are known to navigate and find food through the use of echolocation, a sonar technique in which they systematically emit sounds and interpret the echoes from objects in their surroundings (*1*). It is only in the last 20 years that the auditory nature of this unusual form of environmental sensing has been firmly established. Previously, the sensory process involved had been the subject of years of heated philosophic and scientific debate. This was particularly true in the case of bats and the similar case of sightless humans. The "obstacle sense of the blind" and "facial vision" were terms often used to describe the skill with which blind persons avoided collision with objects in their paths. In 1749, Diderot (*2*), for example, published a comment about a blind man who could judge the proximity of objects by the action of air on his face. Hayes (*3*) has written a very interesting history of early scientific inquiry into the sensory basis of this phenomenon.

Measurement of the extent to which organisms can rely on sonar required controlled experiments. Griffin (*1*) and others have measured the skill of bats, and Kellogg (*4*) has brought the porpois *Tursiops truncatus* to the laboratory for the same purpose. Both of these animals have shown exceptional perceptual abilities involving the use of echolocation sonar, and certain physiological adaptations of their auditory anatomy lead us to expect that humans will be found to be much less skillful with a similar technique (*5*). Measurements of human echo perception are now being made, and a report on some findings from our laboratory at Stanford Research Institute follows.

Important Earlier Studies

It was not till the early 1940's that a group of scientists at Cornell University—Michael Supa, Milton Cotzin, and Karl Dallenbach (*6*)—began a series of laboratory experiments in which all sensory channels except for the auditory channel were found to be irrevelant to "facial vision." They concluded that the perception of echoes reflected from objects approached provides sufficient information for detection and avoidance of many of these objects.

Kohler (*7*) demonstrated individual differences in ability to use echoes in this way and attempted to relate echo perception to human psychoacoustics. His was also the initial attempt to stimulate development of sonar-type mobility aids for the blind.

More recently, Kellogg (*8*), after conducting many experiments to define the echolocation ability of the Atlantic bottlenose dolphin, became interested in the similar sonar of blind persons. A major contribution of Kellogg's work was the demonstration that traditional psychophysical techniques can be used to obtain quantitative measures of this normally ignored ability. Making use of these psychophysical methods, my associates and I have conducted experiments designed to specify some of the characteristics of the human sonar

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